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(54) Title: ADAPTIVE INTERFERENCE-FREE SPREAD-SPECTRUM SYSTEM EMPLOYING BINARY CODE SEQUENCE SETS WITH ZERO CORRELATION ZONE PROPERTIES

Crosscorrelation Function
and its zero zone Z_{CCZ}

Autocorrelation Function
and its zero zone Z_{ACZ}

(57) Abstract

The invention relates to a direct sequence (DS) spread spectrum (SS) system consisting of modulator (1) and demodulator (2) where the spreading sequence (3) with zero correlation zone (ZCZ) properties, and the despreading consists of multiplying the received signal with the same spreading sequence (3), followed by a low pass filter (LPF), decoder and deinterleaver. The bit rate of spreading sequence for each user is normally much higher than the input encoded data bit rate, and therefore spreading the system spectrum. The spread spectrum system, especially the related DS CDMA system, works in an interference-free mode because of the employment of spreading sequences with ZCZ properties, and because of the width of the ZCZ can be adjusted according to transmission channel conditions.

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Description

Adaptive Interference-free Spread-spectrum System Employing Binary Code Sequence Sets with Zero Correlation Zone Properties

Background of the Invention
Field of the Invention

The present invention relates to a binary direct sequence (DS) spread spectrum (SS) system, particularly a DS CDMA system, working in an interference-free mode by employing binary spreading sequence sets having zero correlation zone (ZCZ) properties, so as to eliminate the multiple access interference and other counter measures encountered in the system.

Description of the Background Art

Future digital communication systems will be characterized by high throughput, integrated services, and flexibility. The direct sequence (DS) spread spectrum (SS) systems, especially DS-SS code-division multiple access (CDMA) approaches have been proposed for a variety of digital cellular mobile and wireless personal communication systems. Cellular CDMA systems offer a range of potential advantages over TDMA or FDMA systems, such as high spectrum efficiency, graceful degradation, multipath resistance, inherent frequency diversity and interference rejection, and so on.

A typical direct sequence (DS) spread spectrum system, as shown in Figure 1, consists of modulator (1) and demodulator (2), where the spreading consists of multiplying the input encoded and interleaved data by a binary spreading sequence (3), and the despreading consists of multiplying the received signal with the same binary spreading sequence (3), followed by a low pass filter (LPF), decoder and de-interleaver. The bit rate of spreading sequence for each user is normally much higher than the input encoded data bit rate, and therefore spreading the system spectrum. The ratio of spreading sequence bit rate to input data rate is called spreading factor (SF). When the signal is received at the receiver, the spreading is removed from the desired signal due to the impulsive-like autocorrelation property of the spreading code. When despreading is applied to the interference generated by other user's signals, there is no despreading. That

is, each spread spectrum signal should behave as if it were uncorrelated with every other spread signal using the same band. Therefore, CDMA codes are designed to have very low autocorrelation sidelobes (preferably zero sidelobes) and very low cross-correlations (preferably zero cross-correlations).

5   Given a sequence set $\{a^{(r)}_n\}$ with family size M (the number of sequences in the set), r=1,2,3,...,M, n=0,1,2,3,...,L-1, each sequence is of length L, then one can define the following periodic Auto-Correlation Function (ACF, r=s) and Cross-Correlation Function (CCF, r≠s)

$$R_{r,s}(\tau) = \sum_{n=0}^{L-1} a_n^{(r)} a_{n+\tau}^{(s)}$$

10   where the subscript addition n+τ is performed modulo L.

In ideal case, it is required that the ACF should behave as an impulse, and the CCF should be zeros everywhere. However, it has been proved that it is impossible to design a set of spreading codes with ideal impulsive autocorrelation functions and ideal zero crosscorrelation functions, thus resulting co-channel

15   interference in practical CDMA systems. Generally speaking, the code length L, code family size M, the maximum autocorrelation sidelobe R_{amax}, and the maximum crosscorrelation value R_{cmax} are bounded by certain theoretical limits, such as Welch bound, Sidelnikov bound, Sarwate bound, Levenshtein bound, etc.

Apart from the local noise that is irreducible, there are three kinds of

20   interference which affects the DS CDMA system capacity and system performance, that is, intersymbol interference (ISI), multiple access interference (MAI) and adjacent cell (or channel) interference (ACI). However, all the three kinds of interference can be reduced or even eliminated by employing good multiple access spreading codes.

25   In order to reduce the interference encountered in the DS CDMA system, a number of patents have been published. However, most of the approaches published so far use sophisticated interference cancellers, fast and accurate transmitting power control, variable-rate transmission, and other complicated techniques at the receiver. One previous patent, PCT/CN98/00151

30   (CN1175828A), uses ternary spreading sequences with limited number of sequences and zero correlation region; another patent,

PCT/JP97/03272(JP271858/96), adopts spreading sequences with comb-shaped spectrum.

The present invention was devised in light of the above facts; and in Claim 1, the object of the present invention is to provide a binary coded direct sequence (DS) spread spectrum (SS) communication system which is characterized by the fact that the binary spreading sequence set of length L and size M used in the system has a zero correlation zone Z_{cz} in their periodic autocorrelation functions on both sides of the zero shift and a zero correlation zone Z_{cz} in the periodic cross-correlation functions including the zero shift between any pair of spreading sequences belonging to the code sequence set; and the said spreading code sequence set has length $L=2\times2^i\times10^j\times26^k$, where i, j, k can be zeroes or any positive integers, and family size $2<M<L$, and zero correlation zone $Z_{cz}\leq L/M+1$ for any permitted values of i, j, k, or $Z_{cz}=L/M+1$ for j=k=0 and any permitted value of i; and the frame format used in the system is composed of a central frame which is made by multiplying the binary input and the said ZCZ sequence(s), and additional guard sequences enclosing the central frame, extracted from parts of the central frame. In this way, the multiple access interference, multipath interference and other counter measures can be eliminated efficiently.

Furthermore, in Claim 2, the objects of the present invention are to provide sets of binary sequences with specified length, family size and required ZCZ, so that the system can work in an interference-free mode and can be made adaptive to the channel conditions.

Furthermore, in Claim 3, the object of the present invention is to provide a DS CDMA system where the conventional intracell short channelization codes such as Walsh orthogonal codes or variable-length orthogonal codes are replaced with the binary sequences with big zero correlation zone, which makes it possible to eliminate the inter-path interference.

Furthermore, in Claim 4, the object of the present invention is to provide a DS CDMA system with intercell synchronous operation where the conventional long scrambling code (also called pseudo-noise code) such as m-sequence is replaced with a binary code with big zero correlation zone, which makes it possible to eliminate the multiple access interference.

Furthermore, in Claim 5, the object of the present invention is to provide a DS CDMA system with intercell asynchronous operation where the conventional

long scrambling codes such as Gold codes or Kasami codes are replaced with binary ZCZ codes as presented in this invention, which makes it possible to eliminate the multiple access interference.

Furthermore, in Claim 6, the object of the present invention is to provide an adaptive DS CDMA system by allocating each transmitter a subset of sequences with different ZCZs, so that the transmitter can select a suitable spreading sequence according to channel conditions or system instructions.

Furthermore, in Claim 7, the DS CDMA system described above is applied for down-link communication under the condition of synchronous transmission and for up-link communication under the condition of asynchronous transmission.

Summary of the Invention

. . Although it is impossible to design a set of spreading codes with ideal impulsive autocorrelation functions and ideal zero crosscorrelation functions, it is, however, possible to construct a set of sequences, which possess zero correlation . zones in the ACF/CCF.   The zero correlation zone denoted as Z_{cz} is illustrated in Figure 2 and defined by the following formulas:

$$R_{r,s}(\tau) = \sum_{n=0}^{L-1} a_n^{(r)} a_{n+\tau}^{(s)} = \begin{cases} L, & \tau = 0, \qquad r = s \\ 0, & 0 < |\tau| \le \dfrac{Z_{ACZ} - 1}{2}, \quad r = s \end{cases}$$

$$R_{r,s}(\tau) = \sum_{n=0}^{L-1} a_n^{(r)} a_{n+\tau}^{(s)} = 0, \qquad 0 \le |\tau| \le \dfrac{Z_{CCZ} - 1}{2}, \quad r \ne s$$

$$Z_{cz} = Min\{Z_{ACZ}, Z_{CCZ}\}$$

It should be noted that, although a symmetrical Z_{ACZ} or Z_{CCZ} is assumed in above formulas, in general, the actual ZCZ may not be symmetical to the zero shift.

For simplicity and convenience, the in-phase position ($\tau=0$) of autocorrelation function (ACF peak) is considered to be included in the zero correlation zone. It is therefore that, the zero correlation zone Z_{ACZ} or Z_{CCZ} is an odd number, i.e. the in-phase position plus two side zero positions. If $Z_{ACZ}=Z_{CCZ}$, then $Z_{cz}=Min\{Z_{ACZ}, Z_{CCZ}\}= Z_{ACZ}=Z_{CCZ}$, as is the case of this invention.   In addition, only periodic correlations are considered here.   The reason will be explained later.

In order to accomplish the above-described objects, in Claim 1, the binary

coded direct sequence spread spectrum communication system which is characterized by the fact that the binary spreading sequence set of length L and size M used in the system has a zero correlation zone Z_{cz} in their periodic autocorrelation functions on both sides of the zero shift and a zero correlation zone Z_{cz} in the periodic cross-correlation functions including the zero shift between any pair of spreading sequences belonging to the code sequence set; and the said spreading code sequence set has length $L=2\times2^i\times10^j\times26^k$, where i, j, k can be zeroes or any positive integers, and family size 2<M<L, and zero correlation zone $Z_{cz}\leq L/M+1$ for any permitted values of i, j, k, or $Z_{cz}=L/M+1$ for j=k=0 and any permitted value of i; and the frame format used in the system is composed of a central frame which is made by multiplying the binary input and the said ZCZ sequence(s), and additional guard sequences enclosing the central frame, extracted from parts of the central frame.

Furthermore, in Claim 2, the binary coded direct sequence spread spectrum communication system which is characterized by the fact that in the binary spread spectrum communication system according to claim 1, the said spreading sequences are formed recursively from a starter set with two sequences of length 2 and zero correlation zone $Z_{cz}=1$ or length L>2 with zero correlation zone $Z_{cz}=L/2+1$, or formed by half-truncating a set of ZCZ sequences where the maximum number of truncations is equal to the number of recursions used in constructing the ZCZ sequence set.

Furthermore, in Claim 3, the cellular binary coded direct sequence CDMA communication system which is characterized by the fact that, the channelization spreading sequences of all users communicating in the same cell are chosen from a ZCZ code sequence set as claimed in claims 1 and 2.

Furthermore, in Claim 4, the cellular binary coded direct sequence CDMA communication system which is characterized by the fact that, a binary ZCZ sequence of length L with $Z_{cz}\geq L/2+1$ is chosen as the scrambling code sequence used for intercell synchronous operation.

Furthermore, in Claim 5, the cellular binary coded direct sequence CDMA communication system which is characterized by the fact that, the scrambling code sequences used for intercell asynchronous operation are chosen from a ZCZ code sequence set as claimed in claims 1 and 2.

Furthermore, in Claim 6, the cellular binary coded direct sequence CDMA

system claimed in claim 3 or 5, is characterized by the fact that each transmitter at the base station and mobile station is allocated a single ZCZ spreading sequence or a subset of ZCZ spreading sequences chosen from a ZCZ code set as claimed in claims 1 and 2.

5   Furthermore, in Claim 7, the cellular binary coded direct sequence CDMA system claimed in claim 3, 4, 5 or 6, is applied for down-link communication under the condition of synchronous transmission and for up-link communication under the condition of asynchronous transmission.

10   Brief Description of the Drawings

Figure 1 is a baseband model of DS spread spectrum system.

Figure 2 describes the definition of zero correlation zone, i.e. zero auto-correlation zone Z_{ACZ}, zero cross-correlation zone Z_{CCZ}, and zero correlation zone $Z_{CZ}=Min\{ Z_{ACZ}, Z_{CCZ} \}$.

15   Figure 3 shows the two levels of spectrum spreading at the transmitter. The first level spread code is called channelization code sequence, and the second level spread code is called scrambling code sequence.

Figure 4 shows the intercell and intracell code assignment. At the first level (or layer), a set of orthogonal codes is normally assigned to users in the same

20   cell for discrimination. At the second level, m-sequences are normally for intercell synchronous operation, Gold code and large Kasami sequences are common candidates for intercell asynchronous operation.

Figure 5 shows the normal frame format which results multiple access interference and multipath interference.

25   Figure 6 is a diagram schematically showing the extended frame structure which overcomes the interference problems due to multiple access and multipath by employing the periodic ZCZ codes.

Figure 7 gives an example of interference-free operation in down-link transmission.

30   Figure 8 shows an example of interference-free operation in up-link transmission.

Figure 9a to Figure 9f are diagrams respectively showing the partial periodic correlation functions for ZCZ codes F(1664,16,105), F(1280,16,81), F(1024,16,65), F(832,16,53), F(640,16,41) and F(512,16,33).

Figure 10a to Figure 10f are diagrams respectively showing the partial aperiodic correlation functions for ZCZ codes F(1664,16,105), F(1280,16,81), F(1024,16,65), F(832,16,53), F(640,16,41) and F(512,16,33).

5   Description of the Preferred Embodiments

<<Preface>>

For better understanding of this invention, we will first describe various methods of constructing the sequence sets with desired ZCZ properties, then give the detailed description of the adaptive interference-free DS spread spectrum

10   system, anti-multipath-interference DS CDMA system, anti-cochannel-interference DS CDMA system by employing the ZCZ code sets, and finally, present the extended framing method for practical implementation.

In regards to general code sequence set design method, the present inventors have published a number of publications, especially the book, "Pingzhi

15   Fan and Michael Darnell, Sequence Design for Communications Applications, Research Studies Press, John Wiley & Sons Ltd, London, 1996, ISBN 0-471-96557-x, 516 pages", and the paper, "P. Z. Fan and M. Darnell, On the construction and comparison of periodic digital sequence sets, IEEE Proceedings Communications, Vol.144, No.6, pp.111--117; 1997".

20   As for the binary sequence design with zero correlation zone, there are a few papers, such as "Y. Han, On the minimization of overhead in channel impulse response measurement, *IEEE Trans. Veh. Technol.*, vol. 47, no. 2, pp. 631-636, May 1998", "J. Wolfmann, Almost perfect autocorrelation sequences, *IEEE Trans. Inform. Theory*, vol. 38, no. 4, pp. 1412-1418, July 1992", and "X. M. Deng and P. Z.

25   Fan, Comment on 'On the Minimization of Overhead in Channel Impulse Response Measurement', submitted to *IEEE Trans. Veh. Technol.*, September 1998", which present some results on a single ZCZ sequence with short length, mainly based on computer search.

Up to now, there is no systematic construction for binary ZCZ sequence set

30   with family size larger than 2. According to the zero correlation zone defined above this invention presents several new systematic constructions of ZCZ code sequences with large family size and variable ZCZ values, as described below.

<<ZCZ Sequence Set Construction-I>>

Let F^n be a ZCZ sequence set with family size M, sequence length L, and zero correlation zone Z_{CZ}, or in short, $F(L,M,Z_{CZ})$. To start, let n=0, a basic starter set is chosen as

$$F^0 = \begin{bmatrix} F_{11}^0 & F_{12}^0 \\ F_{21}^0 & F_{22}^0 \end{bmatrix}_{2\times2} = \begin{bmatrix} -1 & 1 \\ -1 & -1 \end{bmatrix}_{2\times2}$$

5

which is a ZCZ sequence set $F(L,M,Z_{CZ}) = (2,2,1)$. Now denote $L_0=2$, the sequence length of starter. From the starter, one can construct a larger ZCZ sequence set $F(L,M,Z_{CZ}) = (2^{2n} L_0, 2^{n+1}, 2^n+1) = (8,4,3)$, n=1, by the following formula,

$$F^1 = \begin{bmatrix} F_{11}^1 & F_{12}^1 & F_{13}^1 & F_{14}^1 \\ F_{21}^1 & F_{22}^1 & F_{23}^1 & F_{24}^1 \\ F_{31}^1 & F_{32}^1 & F_{33}^1 & F_{34}^1 \\ F_{41}^1 & F_{42}^1 & F_{43}^1 & F_{44}^1 \end{bmatrix} = \begin{bmatrix} F_{11}^0 F_{11}^0 & F_{12}^0 F_{12}^0 & (-F_{11}^0)F_{11}^0 & (-F_{12}^0)F_{12}^0 \\ F_{21}^0 F_{21}^0 & F_{22}^0 F_{22}^0 & (-F_{21}^0)F_{21}^0 & (-F_{22}^0)F_{22}^0 \\ (-F_{11}^0)F_{11}^0 & (-F_{12}^0)F_{12}^0 & F_{11}^0 F_{11}^0 & F_{12}^0 F_{12}^0 \\ (-F_{21}^0)F_{21}^0 & (-F_{22}^0)F_{22}^0 & F_{21}^0 F_{21}^0 & F_{22}^0 F_{22}^0 \end{bmatrix} = \begin{bmatrix} -- & ++ & +- & -+ \\ -- & -- & +- & +- \\ +- & -+ & -- & ++ \\ +- & +- & -- & -- \end{bmatrix}_{4\times8}$$

10

where $(-F_{ij}^0)$ is formed by negating sequence F_{ij}^0, each row of F^1 is a ZCZ sequence required.

From the ZCZ sequence set F^1, another ZCZ sequence set F^2, i.e. $F(L,M,Z_{CZ}) = (2^{2n} L_0, 2^{n+1}, 2^n+1) = (32,8,5)$, n=2, can be synthesized by a similar

15 formula,

$$F^2 = \begin{bmatrix} F_{11}^2 & F_{12}^2 & F_{13}^2 & F_{14}^2 & F_{15}^2 & F_{16}^2 & F_{17}^2 & F_{18}^2 \\ F_{21}^2 & F_{22}^2 & F_{23}^2 & F_{24}^2 & F_{25}^2 & F_{26}^2 & F_{27}^2 & F_{28}^2 \\ F_{31}^2 & F_{32}^2 & F_{33}^2 & F_{34}^2 & F_{35}^2 & F_{36}^2 & F_{37}^2 & F_{38}^2 \\ F_{41}^2 & F_{42}^2 & F_{43}^2 & F_{44}^2 & F_{45}^2 & F_{46}^2 & F_{47}^2 & F_{48}^2 \\ F_{51}^2 & F_{52}^2 & F_{53}^2 & F_{54}^2 & F_{55}^2 & F_{56}^2 & F_{57}^2 & F_{58}^2 \\ F_{61}^2 & F_{62}^2 & F_{63}^2 & F_{64}^2 & F_{65}^2 & F_{66}^2 & F_{67}^2 & F_{68}^2 \\ F_{71}^2 & F_{72}^2 & F_{73}^2 & F_{74}^2 & F_{75}^2 & F_{76}^2 & F_{77}^2 & F_{78}^2 \\ F_{81}^2 & F_{82}^2 & F_{83}^2 & F_{84}^2 & F_{85}^2 & F_{86}^2 & F_{87}^2 & F_{88}^2 \end{bmatrix} = \begin{bmatrix} ++++ & ++++ & -+-+ & -+-+ & --++ & --++ & +--+ & +--+ \\ -+-+ & -+-+ & ++++ & ++++ & +--+ & +--+ & --++ & --++ \\ ++++ & ---- & -+-+ & +-+- & --++ & ++-- & +--+ & -++- \\ -+-+ & +-+- & ++++ & ---- & +--+ & -++- & --++ & ++-- \\ --++ & --++ & +--+ & +--+ & ++++ & ++++ & -+-+ & -+-+ \\ +--+ & +--+ & --++ & --++ & -+-+ & -+-+ & ++++ & ++++ \\ --++ & ++-- & +--+ & -++- & ++++ & ---- & -+-+ & +-+- \\ +--+ & -++- & --++ & ++-- & -+-+ & +-+- & ++++ & ---- \end{bmatrix}_{8\times32}$$

where F_{ij}^2 and $F_{(i+4)(j+4)}^2$, $1 \le i,j \le 4$, is given by

$$F_{i1}^2 = F_{i1}^1 F_{i1}^1, \quad \cdots \quad F_{i4}^2 = F_{i4}^1 F_{i4}^1, \quad F_{i5}^2 = (-F_{i1}^1)F_{i1}^1, \quad \cdots \quad F_{i8}^2 = (-F_{i4}^1)F_{i4}^1$$

$$F_{(i+4)1}^2 = F_{i5}^2, \quad \cdots \quad F_{(i+4)4}^2 = F_{i8}^2, \quad F_{(i+4)5}^2 = F_{i1}^2, \quad \cdots \quad F_{(i+4)8}^2 = F_{i4}^2$$

In general, from the ZCZ sequence set F^{n-1} or $F(L,M,Z_{cz}) = (2^{2(n-1)} L_0, 2^n, 2^{n-1}+1)$, a larger ZCZ sequence set F^n or $F(L',M',Z'_{cz}) = (2^{2n} L_0, 2^{n+1}, 2^n+1)$ can be synthesized, as shown below.

$$F^n = \begin{bmatrix} F^n_{11} & \cdots & F^n_{1M} & F^n_{1(M+1)} & \cdots & F^n_{1(2M)} \\ F^n_{21} & \cdots & F^n_{2M} & F^n_{2(M+1)} & \cdots & F^n_{1(2M)} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ F^n_{(2M-1)1} & \cdots & F^n_{(2M-1)M} & F^n_{(2M-1)(M+1)} & \cdots & F^n_{(2M-1)(2M)} \\ F^n_{(2M)1} & \cdots & F^n_{(2M)M} & F^n_{(2M)(M+1)} & \cdots & F^n_{(2M)(2M)} \end{bmatrix}_{M' \times L'}$$

where F^n_{ij} and $F^n_{(i+M)(j+M)}$, $1 \leq i,j \leq M$, is given by

$$F^n_{i1} = F^{n-1}_{i1} F^{n-1}_{i1}, \quad \cdots \quad F^n_{iM} = F^{n-1}_{iM} F^{n-1}_{iM}, \quad F^n_{i(1+M)} = (-F^{n-1}_{i1}) F^{n-1}_{i1}, \quad \cdots \quad F^n_{i(2M)} = (-F^{n-1}_{iM}) F^{n-1}_{iM}$$

$$F^n_{(i+M)1} = F^n_{i(1+M)}, \quad \cdots \quad F^n_{(i+M)M} = F^n_{i(2M)}, \quad F^n_{(i+M)(1+M)} = F^n_{11}, \quad \cdots \quad F^n_{(i+M)(2M)} = F^n_{iM}$$

<<ZCZ Sequence Set Construction-II>>

In order to extend the Construction I, instead of starter,

$$F^0 = \begin{bmatrix} F^0_{11} & F^0_{12} \\ F^0_{21} & F^0_{22} \end{bmatrix}_{2 \times 2} = \begin{bmatrix} -1 & 1 \\ -1 & -1 \end{bmatrix}_{2 \times 2}$$

one can use any starter of order m as defined below,

$$F^0 = \begin{bmatrix} F^0_{11} & F^0_{12} \\ F^0_{21} & F^0_{22} \end{bmatrix} = \begin{bmatrix} -X^m & Y^m \\ -\overleftarrow{Y^m} & -\overleftarrow{X^m} \end{bmatrix}_{2 \times 2^{m+1}}$$

where $\overleftarrow{Y^m}$ denotes the reverse of sequence Y^m, X^m and Y^m is defined recursively by

$$[X^0, Y^0] = [1, \ 1]$$

$$[X^m, Y^m] = [X^{m-1} Y^{m-1}, \ (-X^{m-1}) Y^{m-1}]$$

By using the same recursive formula as defined above, a ZCZ sequence set $F(L,M, Z_{cz}) = (2^{2n+m} L_0, 2^{n+1}, 2^{n+m}+1)$ can be synthesized.

As an example, consider m=2, n=1, one can obtain the following ZCZ set

$F(L,M, Z_{cz}) = (32, 4, 9)$.

$$S_1 = \{++-+++-+---+---+-+-++-+++++---+\}$$
$$S_2 = \{--+++-++++---+++-+++-+---+---+\}$$
$$S_3 = \{+---+---+---+--+++++---++++-+--\}$$
$$S_4 = \{-++++---+-+++--+--+---+---+--\}$$
$$R_{ACF} = \{xxxxxxxxxxxx\ 0000\quad 32\quad 0000\quad xxxxxxxxxxxx\}$$
$$R_{CCF} = \{xxxxxxxxxxxx\ 0000\quad 0\quad 0000\quad xxxxxxxxxxxx\}$$

As another example, consider $m=1$, $n=2$, one can obtain the following ZCZ

set $F(L,M, Z_{cz}) = (64, 8, 9)$.

$$S_1 = \{------+-+-+-+++-++-+-++-++++---+-+-++-+++-++--++-+--+\}$$
$$S_2 = \{++++---+-+--+-+-+++-++-++-+--+-----+-+-+-+++-++-+-++--+\}$$
$$S_3 = \{++--++-+--+---+---+-+-+-+-++++--++-+-+++++---+--+-+\}$$
$$S_4 = \{--+++---++-+-+++++---+-+-+++--++-+-++-+-------+-+-+-+\}$$
$$S_5 = \{-+-+-+-+-------+-++-+++--++-+-+--+-+++++----++-+-+--+++--\}$$
$$S_6 = \{+-+--+++++---++-+-+-++++---+-+-+-+-------+--++-+++--++--\}$$
$$S_7 = \{+--++-+++--++--+-+-+-+-------++-+--+-++++-+-+--+-+++++---\}$$
$$S_8 = \{-++-+--+-++++--+-+-+-+++++---+--++-+++--++--+-+-+-+-------\}$$
$$R_{ACF} = \{xxxxxxxxxxxxxxxxxxxxxxxxxxxx\quad 0000\quad 64\quad 0000\quad xxxxxxxxxxxxxxxxxxxxxxxxxxxx\}$$
$$R_{CCF} = \{xxxxxxxxxxxxxxxxxxxxxxxxxxxx\quad 0000\quad 0\quad 0000\quad xxxxxxxxxxxxxxxxxxxxxxxxxxxx\}$$

<<ZCZ Sequence Set Construction-III>>

By using the third construction, a ZCZ spreading sequence set is formed by

truncating a set of sequences with longer length, according certain rule.

Suppose a ZCZ sequence set $F(L,M,Z_{cz}) = (2^{2n+m} L_0, 2^{n+1}, 2^{n+m}+1)$ is

obtained by using the Construction I or Construction II, then we can synthesize a

shorter ZCZ code with the same family size and smaller ZCZ by simply halving

each sequence t times in set F'', resulting a code set $F(L,M,Z_{cz}) = (2^{2n+m-t} L_0, 2^{n+1},$

$2^{n+m-t}+1)$, where $t \leq n$ for $n>0$, or $t \leq m$ for $n=0$.

Let $n=2$, $m=0$, by using the example code set $F(L,M,Z_{cz}) = (2^{2n+m} L_0, 2^{n+1},$

$2^{n+m}+1) = (32,8,5)$ derived above, two other ZCZ sets can be synthesized by

truncation,

$F(L,M,Z_{cz}) = (32,8,5)$: $S_1 = \{---++++ +-+--+-+\quad ++---++-++-+--+\}$
($t=0$, no truncation) $S_2 = \{++----++ -++-+--+\quad ----++++++-+--+-+\}$
                              $S_3 = \{+-+--+-+ ----++++\quad -++-+--+++---++\}$
                              $S_4 = \{-++-+--+ ++----++\quad +-+--+-+----++++\}$
                              $S_5 = \{------- +-+-+-+-\quad ++--++---++--++-\}$
                              $S_6 = \{++--++-- -++--++-\quad -------+-+-+-+-\}$
                              $S_7 = \{+-+-+-+- -------\quad -++--++-++--++--\}$
                              $S_8 = \{-++--++- ++--++--\quad +-+-+-+--------\}$

R_{ACF}={xxxxxxxxxxxxxx 00 32 00 xxxxxxxxxxxxxx}
R_{CCF}={xxxxxxxxxxxxxx 00 0   00 xxxxxxxxxxxxxx}

$F(L,M,Z_{CZ}) = (16,8,3)$:
(t=1, 1st truncation)

S_1={---++++ +-+--+-+}
S_2={++----++ -++-+--+}
S_3={+-+-+-+ ---++++}
S_4={-++-+--+ ++---++}
S_5={------- +-+-+-+-}
S_6={++--++-- -++--++-}
S_7={+-+++-- -----}
S_8={-++--++- ++--++--}
R_{ACF}={xxxxxxx 0 16 0 xxxxxxx}
R_{CCF}={xxxxxxx 0 0   0 xxxxxxx}

$F(L,M,Z_{CZ}) = (8,8,1)$:
(t=2, 2nd truncation)

S_1={---++++}
S_2={++----++}
S_3={+-+-+-+}
S_4={-++-+--+}
S_5={------}
S_6={++--++--}
S_7={+-+-+-+-}
S_8={-++--++-}
R_{ACF}={xxxx 8 xxxx}
R_{CCF}={xxxx 0 xxxx}

Let n=0, m=4. From the code set $F(L,M,Z_{CZ})$ =(2^{2n+m} L_0, 2^{n+1}, $2^{n+m}+1$) =(32,2,17), four other sets, can be synthesized as shown below,

$F(L,M,Z_{CZ}) = (32,2,17)$:
(t=0, no truncation)

S_1={++-+---+--+----+--+-+++--+----+}
S_2={+----+---+++-+---++++-++-+++-+-}
R_{ACF}={xxxxxxxx 00000000 32 00000000 xxxxxxxx}
R_{CCF}={xxxxxxxx 00000000 0   00000000 xxxxxxxx}

$F(L,M,Z_{CZ}) = (16,2,9)$:
(t=1, 1st truncation)

S_1={++-+---+--+----+}
S_2={+----+---+++-+--}
R_{ACF}={xxxx 0000 16 0000 xxxx}
R_{CCF}={xxxx 0000 0   0000 xxxx}

$F(L,M,Z_{CZ}) = (8,2,5)$:
(t=2, 2nd truncation)

S_1={++-+---+}
S_2={+----+--}
R_{ACF}={xx 00 8 00 xx}
R_{CCF}={xx 00 0 00 xx}

$F(L,M,Z_{CZ}) = (4,2,3)$:
(t=3, 3rd truncation)

S_1={++-+}
S_2={+---}
R_{ACF}={x 0 4 0 x}
R_{CCF}={x 0 0 0 x}

$F(L,M,Z_{CZ}) = (2,2,1)$:
(t=4, 4th truncation)

S_1={++}
S_2={+-}
R_{ACF}={x 2 x}
R_{CCF}={x 0 x}

5

Let n=1, m=2. From the code set $F(L,M,Z_{CZ})$ $=(2^{2n+m} L_0, 2^{n+1}, 2^{n+m}+1)$ $=(32,4,9)$, another set can be synthesized as shown below,

$F(L,M,Z_{CZ}) = (32,4,9)$: $S_1=\{++-+++-+---+---+$ $--+-++-++++---+\}$
(t=0, no truncation) $S_2=\{--+-++-++++---+$ $++-+++-+---+--+\}$
                              $S_3=\{+---+---+---+--$ $-+++++---+-++-+-\}$
                              $S_4=\{-++++---+-++-+-$ $+---+---+---+--\}$
                              $R_{ACF}=\{xxxxxxxxxxxx\ 0000\ 32\ 0000\ xxxxxxxxxxxxx\}$
                              $R_{CCF}=\{xxxxxxxxxxxx\ 0000\ \ 0\ \ \ 0000\ xxxxxxxxxxxxx\}$

$F(L,M,Z_{CZ}) = (16,4,5)$: $S_1=\{++-+++-+---+--+\}$
(t=1, 1st truncation) $S_2=\{--+-++-++++---+\}$
                              $S_3=\{+---+---+---+--\}$
                              $S_4=\{-++++---+-++-+-\}$
                              $R_{ACF}=\{xxxxxx\ 00\ 16\ 00\ xxxxxx\}$
                              $R_{CCF}=\{xxxxxx\ 00\ \ 0\ \ \ 00\ xxxxxx\}$

5   However, the ZCZ set $F(L,M,Z_{CZ}) = (16,4,5)$ cannot be truncated further because of the limitation t≤n for n>0.

<<Other ZCZ Sequence Set Constructions>>

In general, for any given starter F^0 of length 2^{m+1}, a ZCZ code set $F(L,M,$

10   $Z_{CZ})$ $=(2^{2n+m-t} L_0, 2^{n+1}, 2^{n+m-t}+1)$ can be constructed by using Construction I-III, where $L_0=2$, t≤n for n>0, or t≤m for n=0. It should be noted that, in these constructions, the ZCZ is given by $Z_{CZ} =L/M+1=2^{2n+m-t} L_0,/2^{n+1}+1=2^{n+m-t}+1$, for L>M>1; or $Z_{CZ} =1$ for L=M. Therefore, one can write the ZCZ code set as $F(L,M, Z_{CZ}) =(L,M,L/M+1)$ for L>M>1, or $F(L,M, Z_{CZ}) =(L,M,1)$ for L=M.

15   Similarly, by using other basic starters with length $L_0=20$ or $L_0=52$, as shown below, different ZCZ sequence sets can be constructed.

$$F^0 = \begin{bmatrix} F_{11}^0 & F_{12}^0 \\ F_{21}^0 & F_{22}^0 \end{bmatrix}_{2\times 2} = \begin{bmatrix} +--+-+---+ & +------++- \\ -++------+ & -+++-+-++- \end{bmatrix}_{2\times 20}$$

$$F^0 = \begin{bmatrix} F_{11}^0 & F_{12}^0 \\ F_{21}^0 & F_{22}^0 \end{bmatrix}_{2\times 2} = \begin{bmatrix} +++-+-+++-+-----+++--+--- & ---+---+-++-+-+-++---+--- \\ ----+--+-+-+-++-+---++--- & ++++-++--+-++++++-+---++--- \end{bmatrix}_{2\times 52}$$

In the resulting ZCZ code set $F(L,M, Z_{CZ}) =(2^{2n+m-t} L_0, 2^{n+1}, Z_{CZ})$, the basic

20   length L_0 should be replaced with 20 or 52, and the ZCZ is normally less than or equal to L/M+1, i.e. $Z_{CZ} \leq L/M+1$.

<<Adaptive Interference-free Direct Sequence Spread Spectrum System>>

A new type adaptive interference-free direct sequence spread spectrum (AIF-DS-SS) system is proposed in this patent. The AIF-DS-SS is an interference-free system, because the system works in a state in which the spreading sequences have zero Auto-Correlation Functions (ACFs) and Cross-Correlation Functions (CCFs). The AIF-DS-SS is an adaptive system, because the system uses adaptively the desired spreading sequences with variable ZCZ properties according to channel conditions, and thus providing optimal performance under various channel conditions. If the channel condition is getting worse, one can enlarge the zero correlation zone (ZCZ) by choosing a smaller set of ZCZ sequences, otherwise one can reduce the ZCZ in order to accommodate more users.

For a given sequence length L, one can construct different sets of sequences with different family size M and zero correlation zone Z_{cz}, which can be used in the same AIF-DS-SS system to provide different protection against multipath and to provide different system capacity. For a practical SS system, let L=65536, then the possible size M and Z_{cz} are given by Table 1. If one choose M=128, then all the ACFs and CCFs among the sequence set will have zero correlation zone Z_{cz}=513. If channel becomes better, one can use a sequence set $F(L,M, Z_{cz})$=(65536,256,257); if the channel becomes worse, one can skip to $F(L,M, Z_{cz})$=(65536,64,1025) set, and so on.

25

30

Table 1: Adaptation of M and Z_{cz} for a given L

No.	Length L	Size M	ZCZ Z_{cz}
1	65536	65536	1
2	65536	32768	3
3	65536	16384	5
4	65536	8192	9
5	65536	4096	17
6	65536	2048	33
7	65536	1024	65
8	65536	512	129
9	65536	256	257
10	65536	128	513
11	65536	64	1025
12	65536	32	2049
13	65536	16	4097
14	65536	8	8193
15	65536	4	16385
16	65536	2	32769
17	65536	1	65535

For a given family size M, i.e. for a fixed number of sequences in the ZCZ code set, or equivalently the number of subscribers in the AIF-DS-SS system, one can construct different sets of sequences with different lengths L and zero correlation zones Z_{cz}, which can be used in the AIF-DS-SS system to provide different levels of protection against multipath and other counter-measures.   As an illustrating example, let M=16, then some of the possible lengths L and zero correlation zones Z_{cz} are listed in Table 2.   It is assumed here that the system has 16 subscribers.   Each subscriber is allocated a set of sequences with different lengths L and ZCZ Z_{cz}.   Suppose that the sequence of length L=320 is used in the normal channel condition, then all the ACFs and CCFs will have zero correlation zone $Z_{cz}=21$.   If channel becomes better, every active user will be informed by the system to change his spreading sequence of length L=320 to another spreading sequence of length L=256, 160, 128, ...; if the channel becomes worse, every active subscriber should switch his sequence to another sequence with longer length, hence bigger zero correlation zone.

Table 2: Adaptation of L and Z_{cz} for a given M

No.	Length L	Size M	ZCZ Z_{cz}
1	16	16	1
2	32	16	3
3	64	16	5
4	128	16	9
5	160	16	7
6	256	16	17
7	320	16	21
8	416	16	27
9	512	16	33
10	640	16	41
11	832	16	53
12	1024	16	65
13	1280	16	81
14	1664	16	105
...	...	..	..

<<Anti-multipath-interference DS CDMA System by Employing Channelization ZCZ Codes>>

It is well-known that, in commercial narrow band and wide band CDMA system, in order to provide flexible system deployment and operation, there are normally two levels of spectrum spreading, each level required different spreading code allocation, as shown in Figure 3 and Figure 4. By using the multilevel spreading, it is possible to provide waveform orthogonality (at the first level) among all users of the same cell while maintaining mutual randomness (at the second level) only between users of the different cells.

The orthogonality at the first level is normally achieved by multiplying each user's binary input by a short spread sequence (channelization code) which is orthogonal to that of every other user of the same cell. The first level is called channelization. The short orthogonal spread codes used are normally Walsh orthogonal code or variable-length orthogonal code. The variable-length orthogonal code is a modified Walsh code.

However, in the first spreading level, the spreading codes used in every DS CDMA system are either Walsh code or extended Walsh code which can only provide orthogonality at the in-phase shift. As the number of resolvable propagation paths increases, the orthogonality among different users tends to diminish because of increasing inter-path interference and because of the small correlation zone ($Z_{cz}=1$) of the Walsh code and modified Walsh code.

By employing the invented ZCZ code with big ZCZ ($Z_{cz}>1$), the orthogonality among different users of the same cell can be maintained even the multipath problem get more serious. In other words, by allocating the ZCZ code of this invention to all the intracell users, the DS CDMA system will be more tolerant to

5 the multipath interference, and the orthogonality can be achieved in a wide range of channel conditions.

<<Anti-multiple-access-interference DS CDMA System by Employing Scrambling ZCZ Codes>>

10 The mutual randomness at the second level is normally achieved by multiplication of a long pseudorandom sequence (scrambling code) which is cell-specific but common to all users of that cell in the down-link and user-specific in the uplink. The common scrambling code candidates used are maximal length code (m-sequences), Gold code and very large Kasami code.

15 Because the cells in the DS CDMA system are assigned to different scrambling codes, each cell site can use short spreading codes independent from other cells. In intercell synchronous operation, as is the case of IS-95-based systems and North American W-CDMA systems, different cell base stations and different mobile users use different time shifts of the same long sequence in the

20 down-link and up-link. On the other hand, in intercell asynchronous operation, as is the case of European and Japanese W-CDMA system, different cell base stations and different mobile users use different long scrambling code sequences.

However, no matter the m-sequences, Gold codes or very large Kasami codes are used as scrambling codes, the multiple access interference is always a

25 major problem because the cross-correlation values of these sequences are not zeroes. By using the invented ZCZ codes as scrambling codes, the system can work in an optimal multiple access interference-free by using appropriate framing techniques will be described later.

For intercell synchronous operation, one can choose a single ZCZ code of

30 length L with ZCZ $Z_{cz}=L/2+1$, which should be better than m-sequence whose sidelobes are not zeroes. As an example, if the m-sequence of length $L=2^5-1=32767$ used in CDMA (IS-95) system is replaced with a ZCZ sequence of length $L=2^5=32768$, then there is a zero correlation zone $Z_{cz}=16385$, and it is possible to find out a single sequence with bigger ZCZ. For intercell asynchronous operation,

one can choose a set of ZCZ sequences with required ZCZ value as scrambling code, which will be better than Gold or large set Kasami sequences whose ACF sidelobes and CCF values are quite big.

5 <Framing and Other Techniques for the System Implementation>

The systems using the ZCZ codes stated above can carry out interference-free operation only when the interference consists of periodic ZCZ code sequences. As shown in Figure 5, if the receiver input consists of the desired signal $v_s(t)$ composed of a sequence A and interference $v_x(t)$ composed of

10 another sequence B, where the sequences A and B are modulated to A, -A, B and -B by binary information independently, and A is delayed from B by τ, because of asynchronous operation or multipath effect. When this input is demodulated by the receiver, the despreading signal $v_D(t)$ composed of the sequence A that is synchronous to $v_s(t)$ is used. It is assumed that the synchronization is maintained

15 by a conventional technique. Since $v_x(t)$ and $v_D(t)$ are in general asynchronous, it resulting in producing aperiodic CCF in the demodulation process. It is noted that the aperiodic CCF of the ZCZ code as stated above does not have ZCZ or its ZCZ is very small.

To overcome this problem, the system is designed so that the delay time

20 may be limited less than a threshold, and an extended frame format is used. The former can be achieved by sending some timing control signals to mobile stations from the base station in down-link channel of cellular CDMA system. The latter is solved as follows. The spreading sequence A with N chips is incorporated into an extended frame A_E which is made by enclosing the sequence A with the L clip-

25 heading part A_H and the L clip-tail part A_T as shown in Figure 6. All the transmitting frames are composed in this way.

Figure 7 shows an example of receiver input in down-link transmission of a cellular CDMA, when all the signals are transmitted synchronously from the base station. It is assumed that the inter-cell interference is neglected here.

30 As a result, the desired signal $v_s(t)$ and the interference $v_x(t)$ are received at the same time. However, considering multipath effect, the delayed signals $v'_s(t)$ and $v'_x(t)$ are also received with delay τ' and they are considered as interference in the demodulation process.

If the extended frames are used for transmission, and despreading signal

$v_D(t)$ synchronous to $v_S(t)$ is used at the receiver, the boundary between the extended sequences B_E and $-B_E$ does not fall in the despreading sequence A of $v_D(t)$. As long as $|\tau'|<LT_c$ (T_c is the chip period), the interference sequences such as B_E are viewed as periodic sequences for demodulation.

5   Figure 8 shows another example of this idea, the up-link transmission signals from the mobile stations in a cell are asynchronously transmitted to the base station, where multipath effect is neglected for simplicity.   In this case, the difference of arriving time between the desired signal and the interference is denoted by τ''.   Similarly to the down-link case with multipath, as long as $|\tau''|<LT_c$ is

10   maintained, the interference can be viewed periodic.   If multipath effect exists, the following condition should be maintained, i.e.

$$\tau = \max\{\tau', \tau''\} < LT_c, \qquad \begin{pmatrix} \tau': delay\ due\ to\ multipath \\ \tau'': delay\ due\ to\ asynchronous\ access \end{pmatrix}$$

By using the synchronizing techniques stated above, the system with ZCZ codes can operate in the state of interference-free. As explained above, this

15   system is very useful when applied for not only up-link (asynchronous) transmission but also down-link (synchronous) transmission with multipath effect.

In order for the DS CDMA system to be adaptive to the channel conditions, each transmitter at the base station and mobile station can be allocated either one ZCZ spreading sequence or several ZCZ spreading sequences with different ZCZ.

20   It should be noted that the ZCZ spreading code sequences presented above have not only an ideal zero correlation zone, as shown in Figure 9, but also a very small, although not identical zero, aperiodic correlations within the ZCZ region, as shown in Figure 10.

Claims

1. A binary coded direct sequence spread spectrum communication system which is characterized by the fact that the binary spreading sequence set of length L and size M used in the system has a zero correlation zone Z_{cz} in their periodic autocorrelation functions on both sides of the zero shift and a zero correlation zone Z_{cz} in the periodic cross-correlation functions including the zero shift between any pair of spreading sequences belonging to the code sequence set; and the said spreading code sequence set has length $L=2\times2^i\times10^j\times26^k$, where i, j, k can be zeroes or any positive integers, and family size 2<M<L, and zero correlation zone $Z_{cz}\leq L/M+1$ for any permitted values of i, j, k, or $Z_{cz}=L/M+1$ for j=k=0 and any permitted value of i; and the frame format used in the system is composed of a central frame which is made by multiplying the binary input and the said ZCZ sequence(s), and additional guard sequences enclosing the central frame, extracted from parts of the central frame.

2. A binary coded direct sequence spread spectrum communication system which is characterized by the fact that in the binary spread spectrum communication system according to claim 1, the said spreading sequences are formed recursively from a starter set with two sequences of length 2 and zero correlation zone $Z_{cz}=1$ or length L>2 with zero correlation zone $Z_{cz}=L/2+1$, or formed by half-truncating a set of ZCZ sequences where the maximum number of truncations is equal to the number of recursions used in constructing the ZCZ sequence set.

3. A cellular binary coded direct sequence CDMA communication system which is characterized by the fact that, the channelization spreading sequences of all users communicating in the same cell are chosen from a ZCZ code sequence set as claimed in claims 1 and 2.

4. A cellular binary coded direct sequence CDMA communication system which is characterized by the fact that, a binary ZCZ sequence of length L with $Z_{cz}\geq L/2+1$ is chosen as the scrambling code sequence used for intercell synchronous operation.

5. A cellular binary coded direct sequence CDMA communication system which is

characterized by the fact that, the scrambling code sequences used for intercell asynchronous operation are chosen from a ZCZ code sequence set as claimed in claims 1 and 2.

5   6. According to claim 3 or 5, the cellular binary coded direct sequence CDMA system is characterized by the fact that each transmitter at the base station and mobile station is allocated a single ZCZ spreading sequence or a subset of ZCZ spreading sequences chosen from a ZCZ code set as claimed in claims 1 and 2.

10 7. According to claim 3, 4, 5 or 6, the cellular binary coded direct sequence CDMA system is applied for down-link communication under the condition of synchronous transmission and for up-link communication under the condition of asynchronous transmission.

Figure 1

Figure 2

Crosscorrelation Function
and its zero zone Z_{CCZ}

Autocorrelation Function
and its zero zone Z_{ACZ}
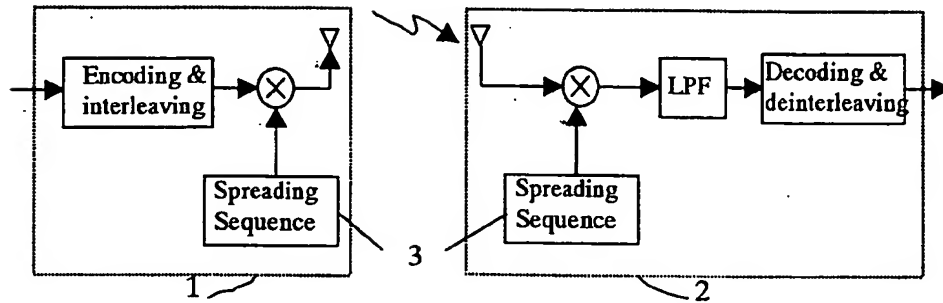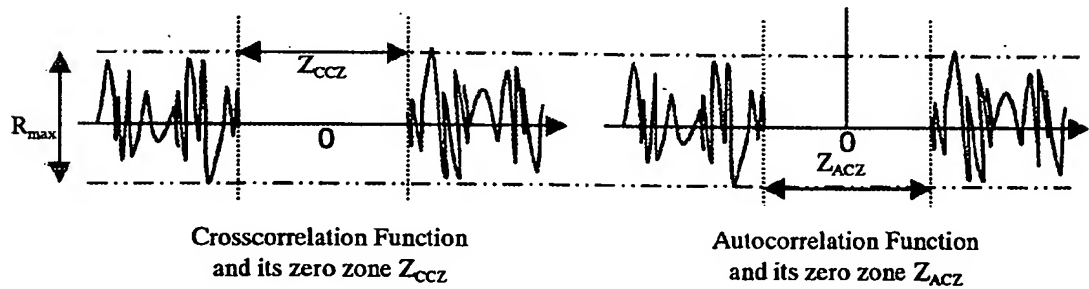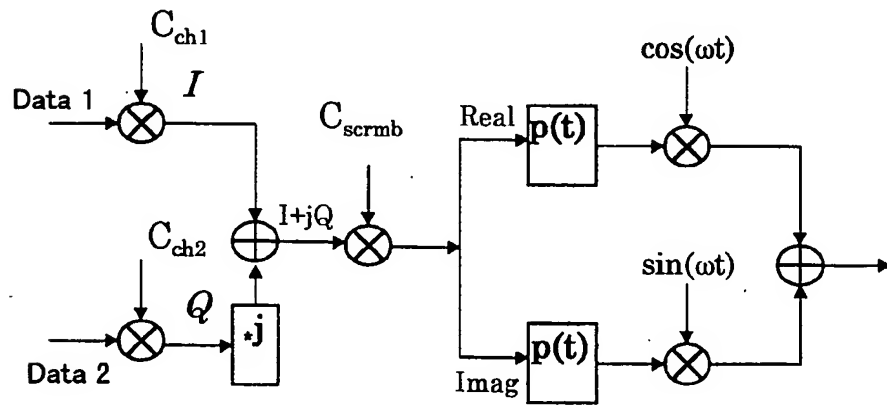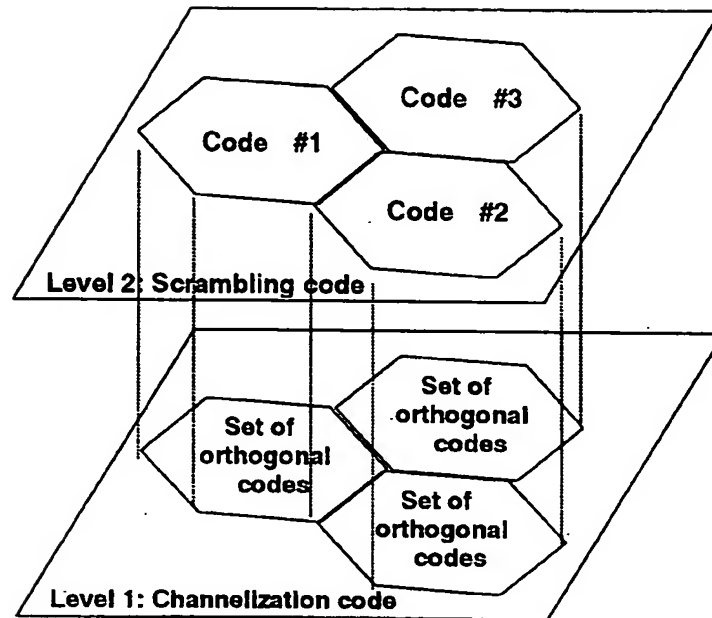
Figure 3
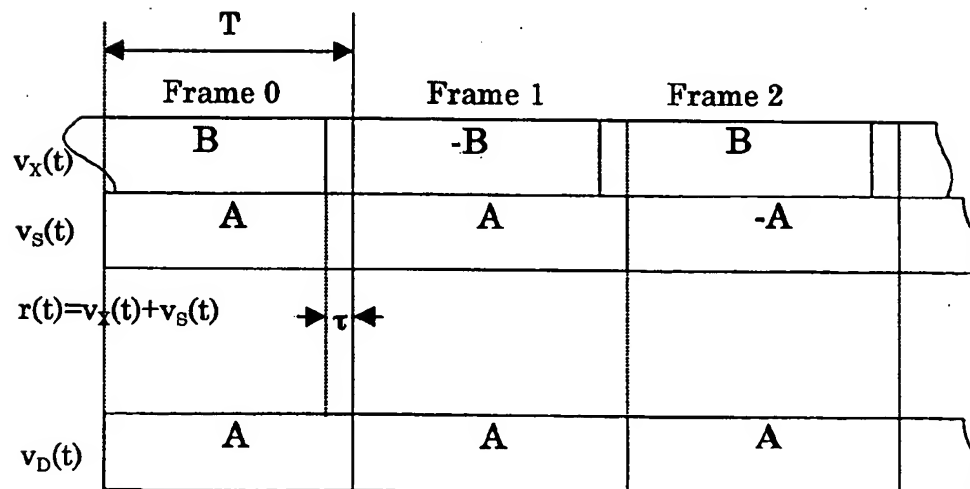
Figure 4
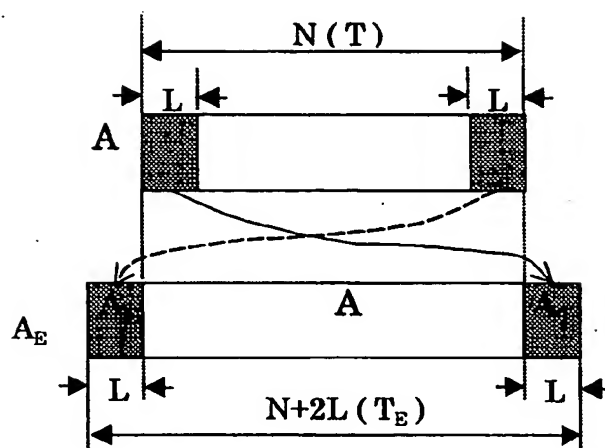
Figure 5
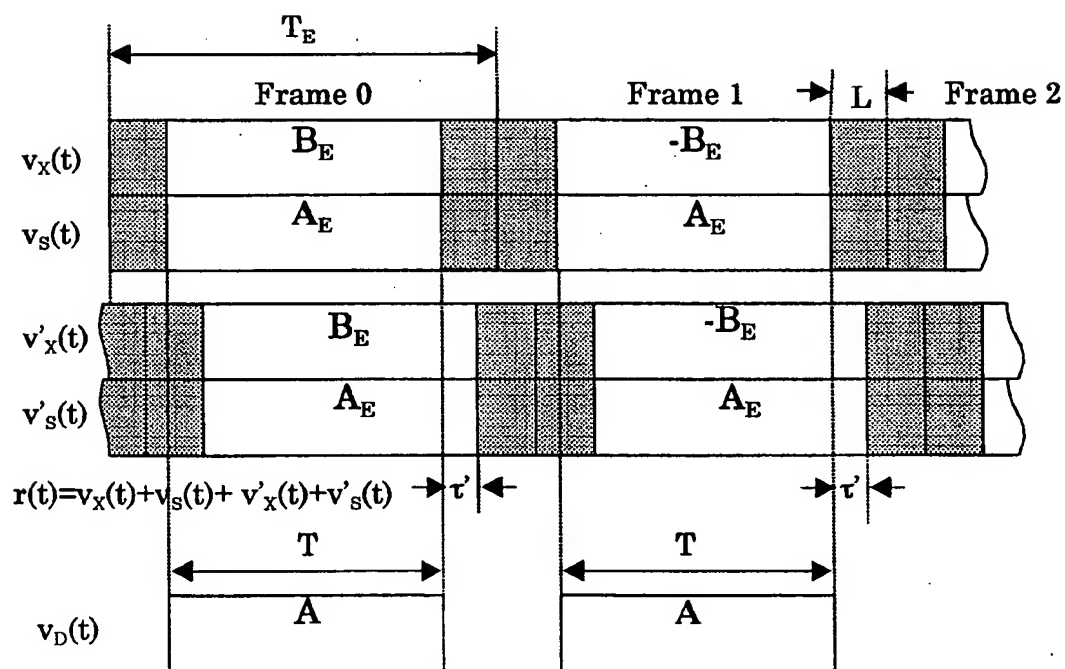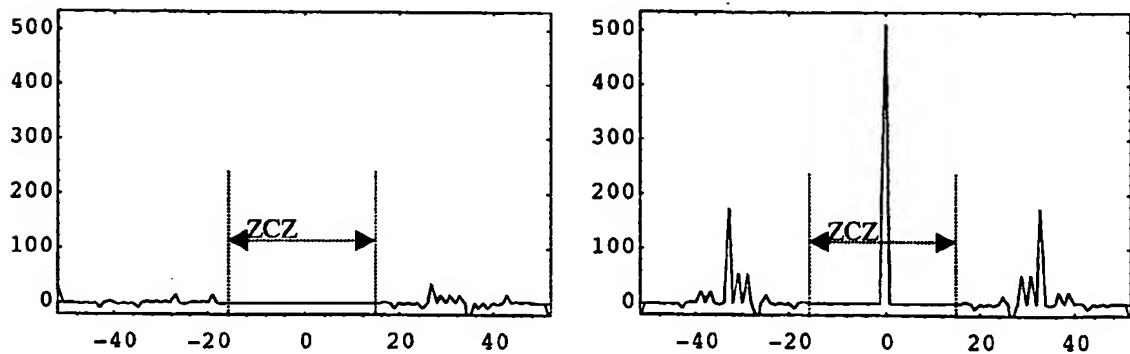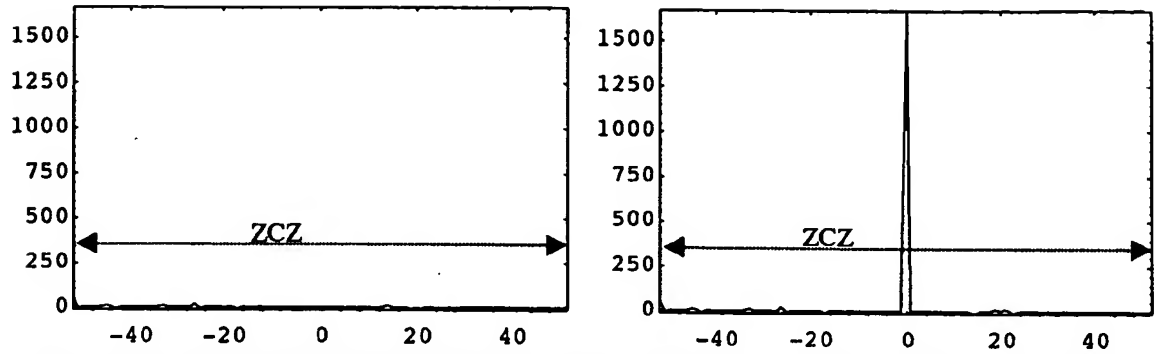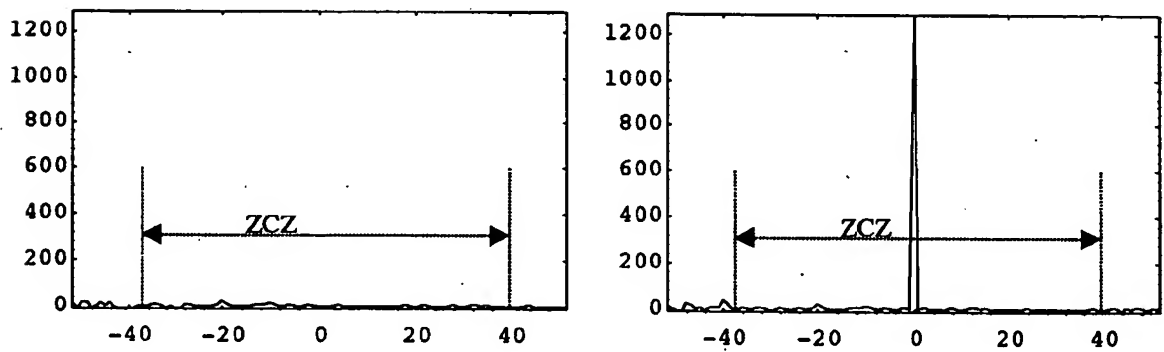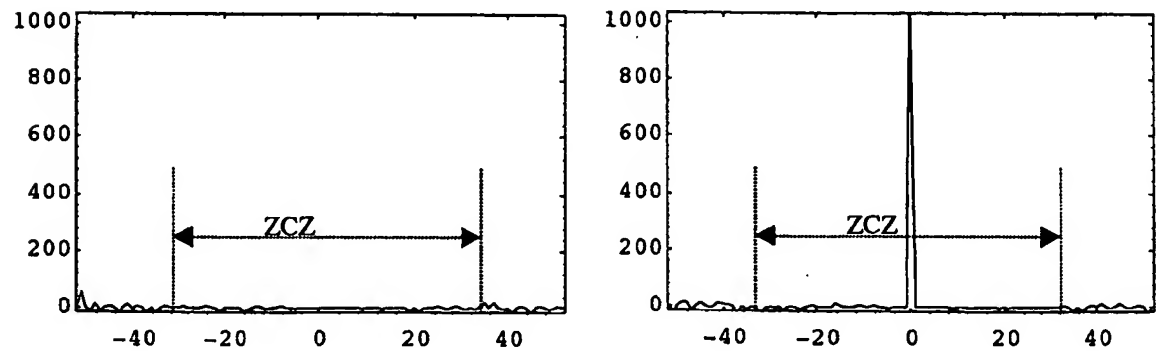
Figure 6

Figure 7
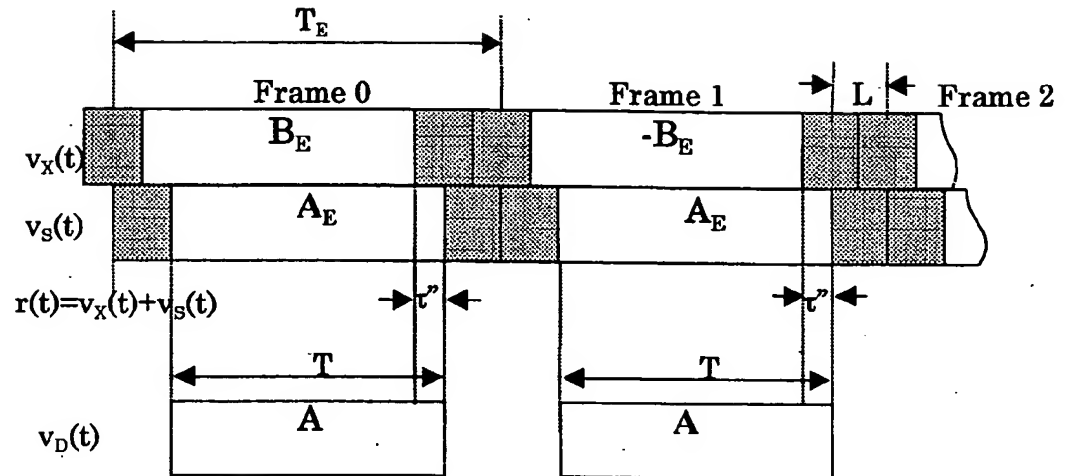
Figure 8
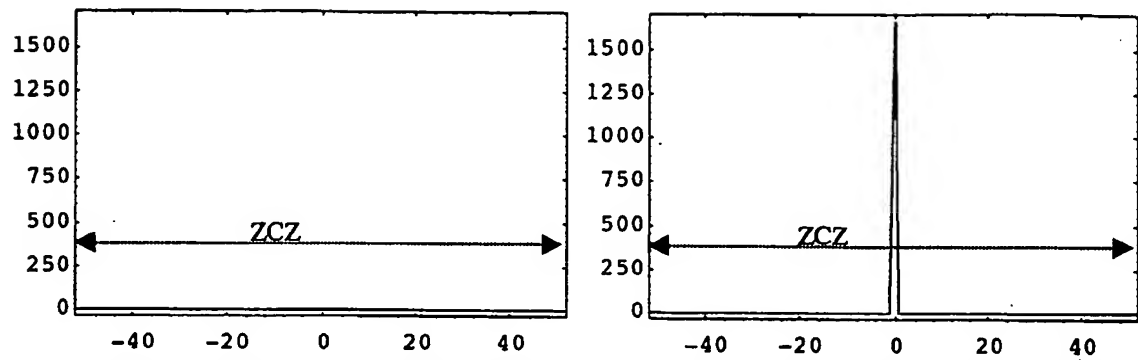
Figure 9

Figure 9a: CCF and ACF Examples for ZCZ Sequence Set $(L, M, Z_{cz}) = (1664, 16, 105)$
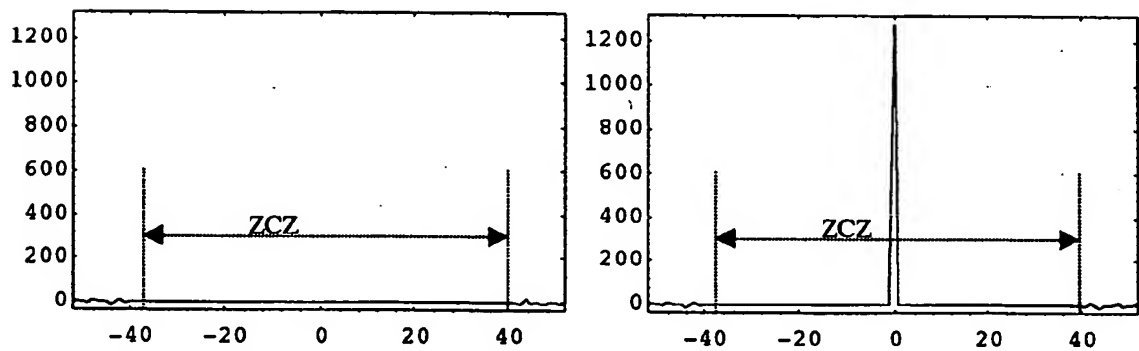
Figure 9b: CCF and ACF Examples for ZCZ Sequence Set $(L, M, Z_{cz}) = (1280, 16, 81)$
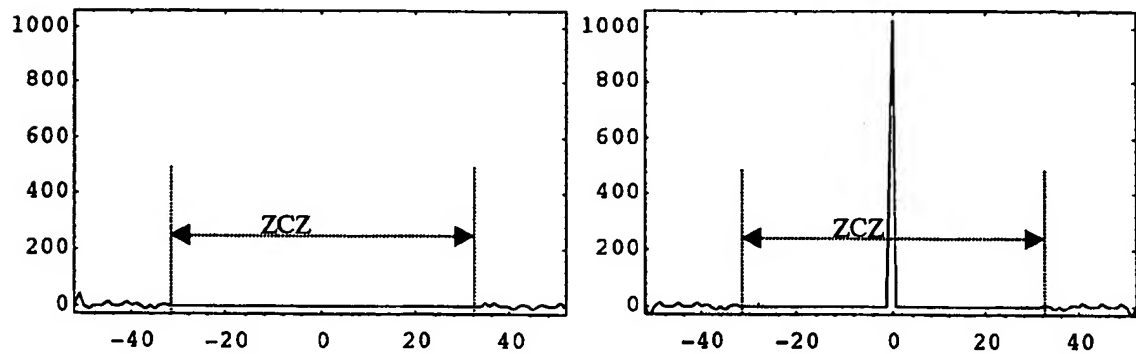
Figure 9c: CCF and ACF Examples for ZCZ Sequence Set $(L, M, Z_{cz}) = (1024, 16, 65)$
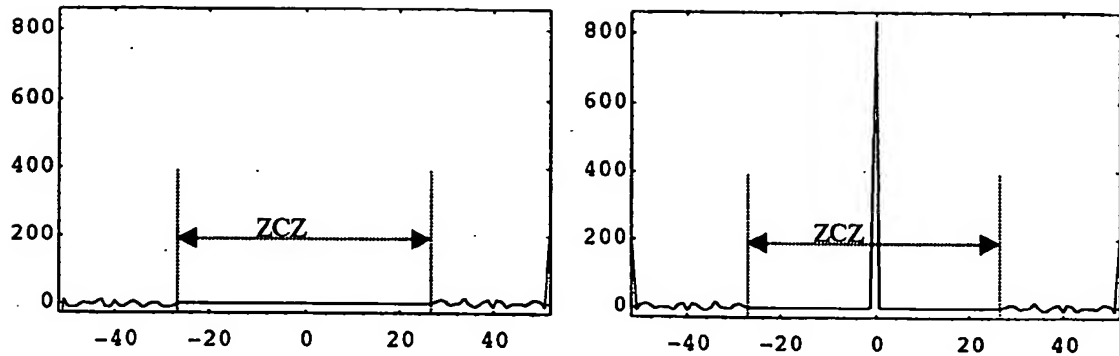
Figure 9d: CCF and ACF Examples for ZCZ Sequence Set $(L,M,Z_{cz})=(832,16,53)$
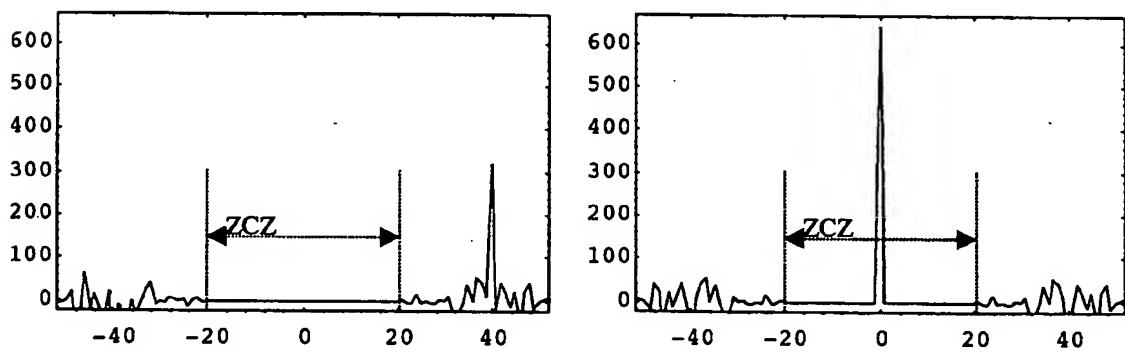
Figure 9e: CCF and ACF Examples for ZCZ Sequence Set $(L,M,Z_{cz})=(640,16,41)$

Figure 9f: CCF and ACF Examples for ZCZ Sequence Set $(L,M,Z_{cz})=(512,16,33)$

Figure 10

Figure 10a: Aperiodic CCF & ACF Examples for ZCZ Sequence Set (L,M,Z$_{cz}$)=(1664,16,105)

Figure 10b: Aperiodic CCF & ACF Examples for ZCZ Sequence Set (L,M,Z$_{cz}$)=(1280,16,81)

Figure 10c: Aperiodic CCF & ACF Examples for ZCZ Sequence Set (L,M,Z$_{cz}$)=(1024,16,65)

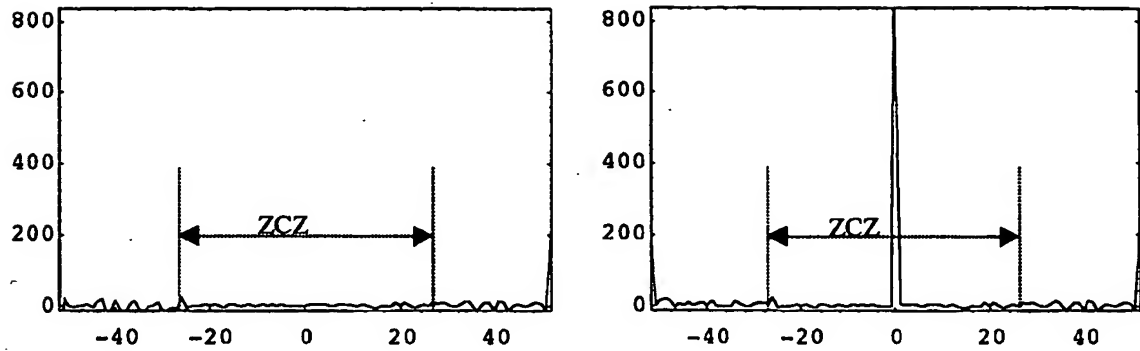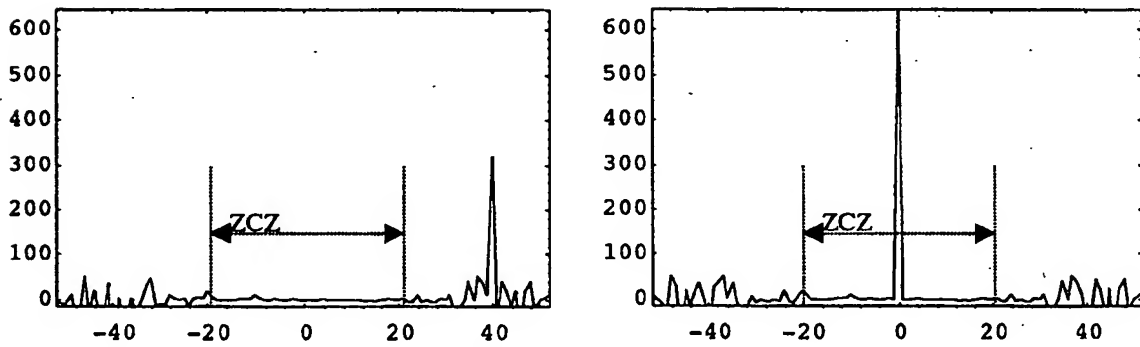Figure 10d: Aperiodic CCF & ACF Examples for ZCZ Sequence Set $(L,M,Z_{cz})=(832,16,53)$

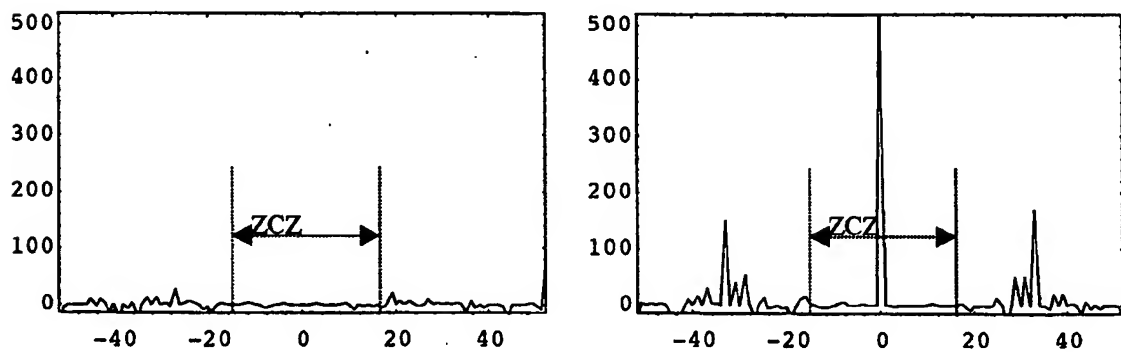Figure 10e: Aperiodic CCF & ACF Examples for ZCZ Sequence Set $(L,M,Z_{cz})=(640,16,41)$

Figure 10f: Aperiodic CCF & ACF Examples for ZCZ Sequence Set $(L,M,Z_{cz})=(512,16,33)$

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7   H04B7/26   H04J13/04   H03M13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   H04J   H04B   G06F   H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CRUSELLES E J ET AL: "SPREADING CODES GENERATOR FOR WIRELESS CDMA NETWORKS" WIRELESS PERSONAL COMMUNICATIONS,NL,KLUWER ACADEMIC PUBLISHERS, vol. 7, no. 1, 1 May 1998 (1998-05-01), pages 69–86, XP000750753 ISSN: 0929-6212 page 75, paragraph 3 –page 76, paragraph 4 page 70, last paragraph –page 71, paragraph 5 abstract; figures 2,3; table 2	1-7
	—/—	

[X] Further documents are listed in the continuation of box C.	[ ] Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 May 2000	22/05/2000

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	TANIMOTO M ET AL: "Synchronous spread-spectrum multiplex communication system using a modified M-sequence" ELECTRONICS AND COMMUNICATIONS IN JAPAN, JULY 1984, USA, vol. 67, no. 7, pages 70-77, XP002136744 ISSN: 0424-8368 page 71, left-hand column, last paragraph -page 72, right-hand column, paragraph 2; figures 2,4 abstract	1
A	WOLFMANN J: "ALMOST PERFECT AUTOCORRELATION SEQUENCES" IEEE TRANSACTIONS ON INFORMATION THEORY,US,IEEE INC. NEW YORK, vol. 38, no. 4, 1 July 1992 (1992-07-01), pages 1412-1418, XP000287159 ISSN: 0018-9448 cited in the application abstract	1

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